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Evidence for threshold effects in the pass-through of carbon prices to wholesale electricity prices

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Abstract

This article considers the evidence for threshold effects in the relationship between electricity and emission permit prices in France and Germany during the second phase of the EU ETS. Specifically, we compare linear and nonlinear threshold models of electricity prices using Hansen's (2000) approach of sample splitting and threshold estimation. We find evidence of nonlinear threshold effects in both countries. The estimated carbon price thresholds are 14.94 and 12.57 euros in France and Germany, respectively. The carbon price threshold in France perfectly coincides with the well-known carbon spot price structural break occurred on October 2008. This is not the case for the carbon price threshold in Germany. An in-depth analysis reveals that during the period before October 2008, carbon prices were not reflected in electricity prices in either countries. This is mainly due to uncertainties about the future of the EU ETS that have led electricity producers to adopt a wait and see behavior. After October 2008, French electricity producers passthrough the price of emission permits into electricity prices in a linear way, while their German counterparts do so nonlinearly.

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1 Introduction

Electricity generation is the most polluting activity covered in the European Union Emission Trading Scheme (EU ETS). As such, we may expect the price of emission permits to impact electricity prices. Most articles dealing with the relationship between the price of emission allowances and electricity prices (Sijm *et al.*, 2005 and 2006 ; Honkatukia *et al.*, 2008 ; Bunn and Fezzi, 2008; Fabra and Reguant, 2014) have appealed linear models (OLS, VARs, VECM, etc.). More recent work has however suggested that the impact of the carbon price on electricity prices is nonlinear and depends significantly on the country's energy mix. Kirat and Ahamada (2011) and Ahamada and Kirat (2015) consider the impact of carbon trading on electricity prices in France and Germany during both phases of the EU ETS: 2005-2007 and 2008-2012. They first use a linear model before introducing nonlinearity via a structural change in the carbon spot price series, which break affects the model parameters.

There is a fundamental debate between econometricians over the presence of nonlinearity due to structural change and that due to a threshold effect. We can think of the structural change model (changepoint model) as a special case of the threshold model if we imagine time as the threshold variable. There is a substantial literature dealing with threshold models (see Hansen, 2011). Among these, Hansen (2000) develops a statistical theory for threshold estimation in the regression context and asymptotic distribution theory for the regression estimates.

This article compares a linear model of electricity prices, as in Kirat and Ahamada (2011) and Ahamada and Kirat (2015), to a nonlinear threshold model using Hansen's (2000) approach of sample splitting and threshold estimation. Testing for threshold effects depending on the price of carbon is of primary importance in the context of electricity-price models including the carbon price as a regressor. Indeed, market imperfections such as risk, uncertainties, lack of information and transaction costs (Stavins, 1995) are factors that could affect the pass-through rate of carbon price to electricity prices.

The model that we propose will allow us to see whether there exists a carbon price at which the behavior of electricity producers changes. We focus on the French and German electricity markets during the Kyoto commitment period of the EU ETS (2008-2012).[1] The results below reject the null hypothesis of linearity in favor of the alternative of a nonlinear threshold effect in both countries. The in-depth scrutiny of the results reveals that both French and German electricity producers do not include the emission permit price in the cost of electricity generation before October 2008. After October 2008, French electricity producers pass through the emission permit price to electricity price in a linear way, while their German counterparts do it non-linearly.

[1] While in Germany more than 50% of electricity is generated using coal and lignite, France produces almost 80% of its electricity from nuclear energy, with fossil fuels accounting for just 9% to 10%. Moreover, producing electricity from fossil fuel plants is more costly and emits more CO2 compared to nuclear plants. Consequently, the electricity and carbon price relationships may be different in the two countries.

2 The threshold regression model

2.1 Threshold model

The linear model considered by Kirat and Ahamada (2011) and Ahamada and Kirat(2015) is very close to the following:

$$P_t^{elec} = \alpha_0 + \alpha_1 P_{t-1}^{elec} + \phi P_t^{gas} + \delta P_t^{coal} + \gamma P_t^{carbon} + \lambda_1 T_t + \lambda_2 T_t^2 + \sum_{j=2}^{5} \psi_j season_j + \varepsilon_t \quad (1)$$

where P_t^y is the logarithm of the price of commodity y in period t, and T is the temperature variable. The square of the temperature is included to capture the well-known nonlinear effect of temperature on electricity prices. The seasonal dummies $season_j$, $j = 1,..,5$, correspond to the five business days of the week ($j = Monday, ..., Friday$). This regression can also be written as follows:

$$P_t^{elec} = \beta X_t + \varepsilon_t \quad (2)$$

where $\beta = (\alpha_0, \alpha_1, \phi, \delta, \gamma, \lambda_1, \lambda_2, \psi_2, \psi_3, \psi_4, \psi_5)$ and $X_t = (1, P_{t-1}^{elec}, P_t^{gas}, P_t^{coal}, P_t^{carbon}, T_t, T_t^2, season_2,\ season_3, season_4, season_5)'$. We look for a possible nonlinear effect of carbon price on electricity prices using the following threshold regression model:

$$P_t^{elec} = \begin{cases} \beta^{(1)} X_t + \varepsilon_t & if \quad P_t^{carbon} \leq p \\ \beta^{(2)} X_t + \varepsilon_t & if \quad P_t^{carbon} > p \end{cases} \quad (3)$$

where $\beta^{(1)} = (\alpha_0^1, \alpha_1^1, \phi^1, \delta^1, \gamma^1, \lambda_1^1, \lambda_2^1, \psi_2^1, \psi_3^1, \psi_4^1, \psi_5^1)$ and $\beta^{(2)} = (\alpha_0^2, \alpha_1^2, \phi^2, \delta^2, \gamma^2, \lambda_1^2, \lambda_2^2, \psi_2^2, \psi_3^2, \psi_4^2, \psi_5^2)$. The threshold parameter p is considered to be unknown. It is convenient to rewrite (3) as follows:

$$P_t^{elec} = \beta^{(2)} X_t + \delta X_t(p) + \varepsilon_t \quad (4)$$

where $\delta = \beta^{(1)} - \beta^{(2)}$, $X_t(p) = X_t I(\ P_t^{carbon} \leq p)$ and $I(.)$ is the indicator function. We want to estimate $\beta^{(1)}$, $\beta^{(2)}$ and p if the null hypothesis of linearity is rejected, i.e. $H_0 : \ \delta = 0$ in equation (4).

2.2 Nonlinearity Tests and Estimation

We first examine the null hypothesis of linearity in equation (4), $H_0 : \ \delta = 0$. Without an *a priori* fixed value of p in regression (4), it is not easy to make any statistical inference regarding δ. In this case p is a nuisance parameter which is not identified under the null hypothesis. To avoid this problem, Hansen (1996) developed a simulation technique producing a p-value statistic for the inference of δ. His approach does not require fixing an *a priori* value of p and allows for possible heteroskedasticity in (4). The computation method of the threshold estimate $\widehat{p}$ uses the concentrated sum of squared errors function from (4):

$$S(p) = \sum_{t=1}^{T} \left(P_t^{elec} - \widehat{\beta^{(2)}}(p) X_t - \widehat{\delta}(p) X_t(p) \right)^2 \quad (5)$$

and the threshold estimate $\widehat{p}$ is the value that minimizes $S(p)$:

$$\widehat{p} = \underset{p\epsilon\Gamma}{\arg\min} S(p) \quad (6)$$

where Γ is a bounded set of elements of $\{P_t^{carbon}, t = 1, ..., T\}$ and can be approximated by a grid (see Hansen, 2000). Finally, the slope estimates in the threshold model (3) can be computed via $\widehat{\beta^{(2)}}(\widehat{p})$ and $\widehat{\delta}(\widehat{p})$. Hansen (2000) also developed asymptotic distribution theory for the threshold estimate $\widehat{p}$, and proposed asymptotic confidence intervals by inverting the likelihood-ratio statistic. His approach again allows for possible heteroskedasticity in (4).

3 Application

3.1 Data

We use electricity prices in €/MWh from the day-ahead base-load[2] contracts covering the French and German markets which are traded on the EPEX spot exchange.[3] Day-ahead contracts are traded on a given day for the delivery of electricity one day ahead. The data we use here are of weekday frequency and run from March 3rd, 2008 to December 30th, 2010.[4] The carbon spot price comes from the Bluenext environmental trading exchange expressed in € per ton. With respect to the primary energy markets, we appeal to the following price series expressed in € per MWh: i) the gas price of the month-ahead future contract traded on the Zeebrugge hub; and ii) the coal price of the month-ahead future contract Coal CIF ARA. The temperature information comes from the European Climate Assessment Dataset,[5] and is calculated as the average temperatures recorded at representative regional weather stations. Our final sample consists of 724 observations.

3.2 Results and interpretations

We first check that there is evidence of a threshold effect associated with the emission permit price. We do so by employing both the F-test to consider a threshold under homoskedastic errors and the heteroskedasticity-consistent Lagrange multiplier (LM) test for a threshold of Hansen (1996, 2000). The p-values of test-statistics for the null $H_0 : \delta = 0$ (conditional on $p = \widehat{p}$) are computed using a bootstrap with 10000 replications.

Table 1 and Figures 1 and 2 show the results of these tests of no threshold against the alternative of a threshold effect in both Germany and France. These results strongly reject the null hypothesis of no threshold in favor of the alternative of a threshold at the 95% confidence level in both countries. Figures 3 and 4 plot the F-test statistic as a function of the threshold in the carbon-allowance price in Germany and France, respectively. The dotted lines in the graphs represent the critical values at the standard significance level of 95%. The null hypothesis of linearity is rejected in favor of the alternative of a threshold effect in both countries. Linearity is rejected if the F-test statistic exceeds the critical value. Since the F-test is valid only with homoskedastic errors, it needs to be complemented by an LM test, as in Table 1. We thus

[2]The electricity base-load price is the price on the block for 24 hours. This is an arithmetic average price over the 24 hours of the day (from 0h to 23h).

[3]EPEX Spot exchange is a holding company created by the collaboration between EEX Power Spot and Powernext SA, respectively the German and French electricity stock exchanges.

[4]Although the second phase of the EU ETS lasts in 2012, we restrict our sample to the period 2008-2010 in order to make our results comparable with those in Ahamada and Kirat (2015).

[5]Klein Tank *et al.*, "Daily dataset of 20th-century surface air temperature and precipitation series for the European Climate Assessment", 2011, available at http://eca.knmi.nl.

Table 1: Test results of no threshold against the alternative of a threshold

	Germany		France	
Assumption regarding errors	Homoskedastic	Heteroskedastic	Homoskedastic	Heteroskedastic
Test for no threshold	31.161	25.309	32.269	27.776
	(0.039)	(0.046)	(0.027)	(0.017)

Note: The bootstrapped p-values computed with 10000 replications are in (); The F-test and LM-test are used to test for no threshold under the assumption of homoskedastic and heteroskedastic errors, respectively.

consider the threshold-test results which are indicated by the results from the homoskedasticity tests which are shown in the last row of Table 2. Specifically, the relevant threshold tests are the F-test in Germany and the LM-test in France, since we do not reject homoskedasticity in the residuals of the threshold model in Germany but we do so for France.

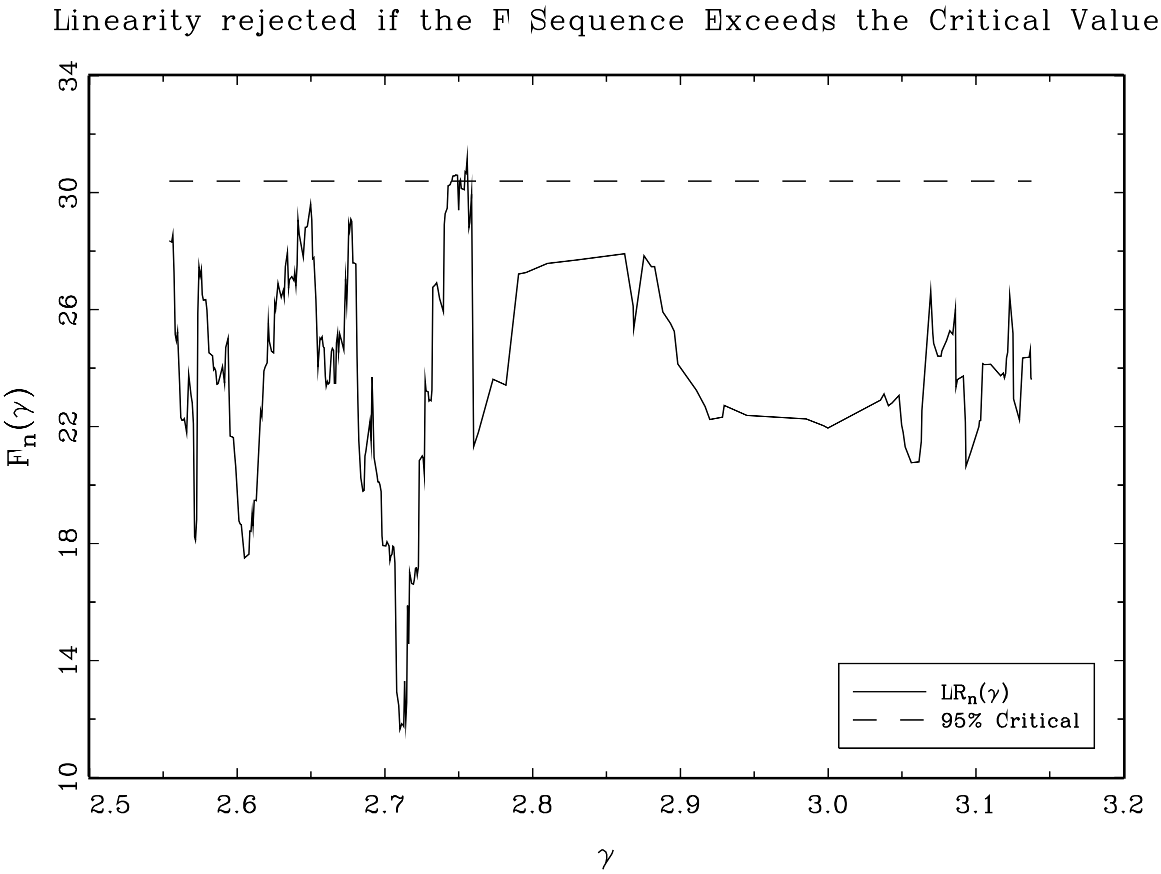

Figure 1: Test for linearity against nonlinearity in Germany.

Figures 3 and 4 show the graphs of the normalized likelihood-ratio statistic as a function of the threshold in the carbon-allowance price (in logs) in Germany and France, respectively. The estimates of the carbon thresholds (in logs) are the values that minimize these graphs, which occur at 2.531 (12.57 €/ton) and 2.704 (14.94 €/ton) in Germany and France, respectively. The dotted lines in the graphs represent the 95% critical values, so we can read off the asymptotic 95% confidence intervals from the graphs where the normalized likelihood-ratio sequence crosses the dotted lines. These confidence intervals (in logs) are $[2.5257, 2.5313]$ in

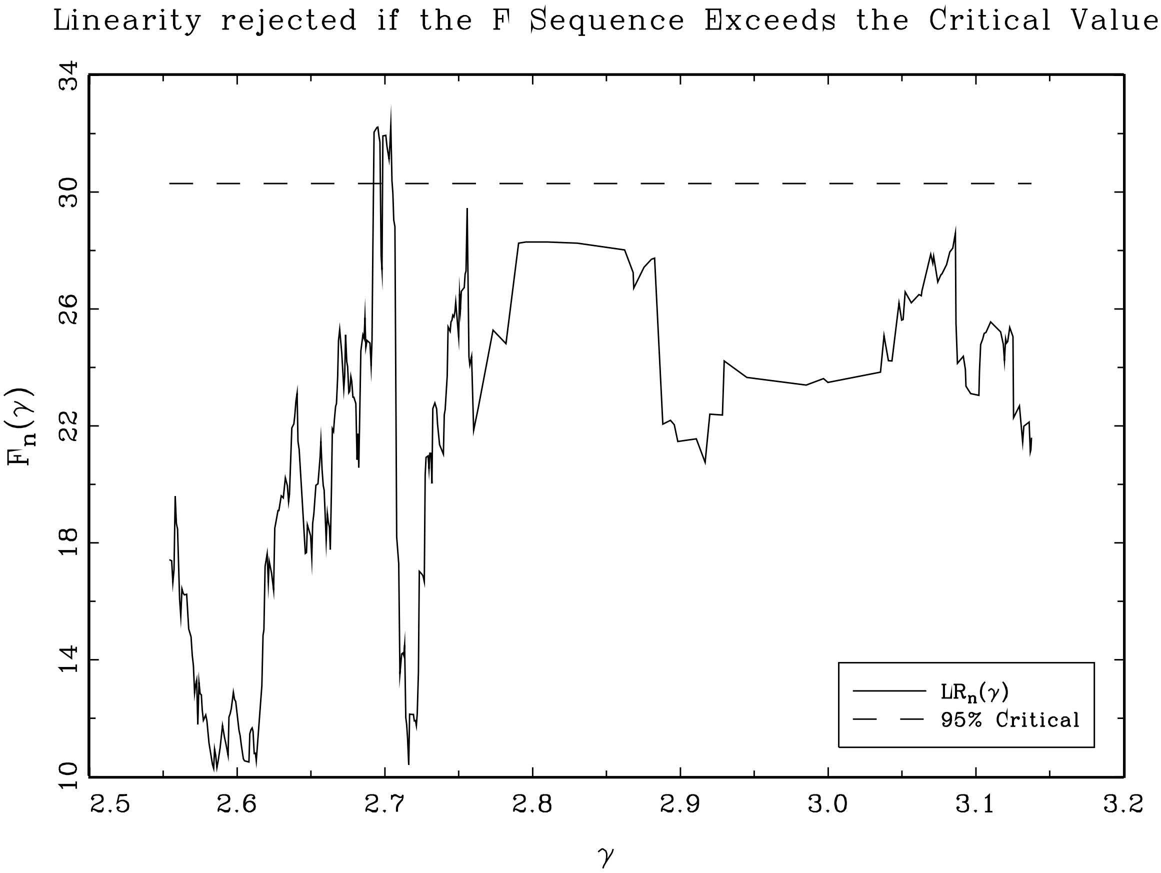

Figure 2: Test for linearity against nonlinearity in France.

Germany and $[2.6925, 2.7555]$ in France. The corresponding 95% confidence intervals in €/ton are $[12.50, 12.58]$ and $[14.77, 15.73]$, respectively. These results show that there is a reasonable evidence for a two-regime specification in both countries. Figures 3 and 4 show that the confidence intervals are fairly tight, so the uncertainty over the values of these thresholds is correspondingly small.

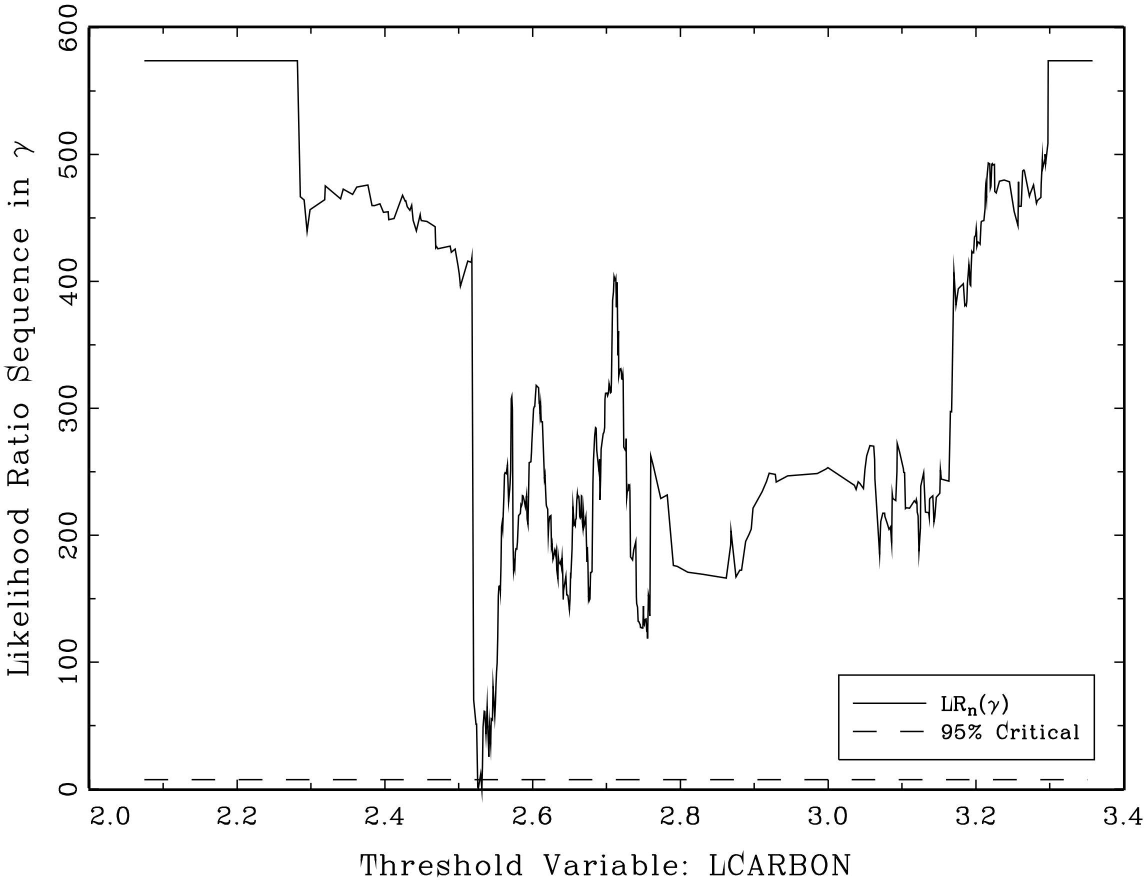

Figure 3: Germany: Confidence interval construction for the threshold (in logs).

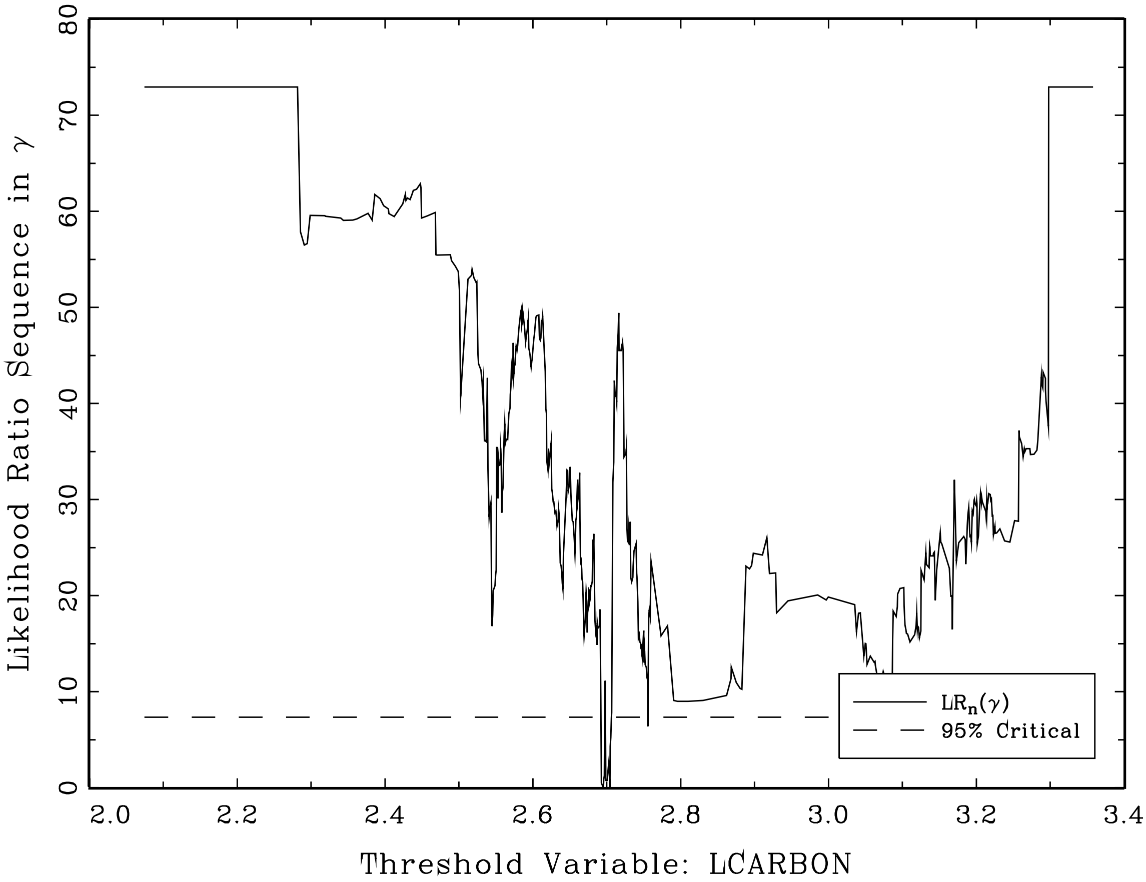

Figure 4: France: Confidence interval construction for the threshold (in logs).

Table 2: Estimation Results

Country	Germany			France		
	Linearity	Nonlinearity		Linearity	Nonlinearity	
Threshold ($\widehat{p}$)		12.57€ [12.50 ; 12.58]			14.94€ [14.77 ; 15.73]	
Regime		Below threshold	Above threshold		Below threshold	Above threshold
P_{t-1}^{elec}	0.575***	0.218	0.607***	0.730***	0.641***	0.794***
	(0.072)	(0.166)	(0.052)	(0.043)	(0.044)	(0.076)
P_t^{gas}	0.215***	0.707***	0.174***	0.113***	0.205***	0.045
	(0.050)	(0.178)	(0.045)	(0.042)	(0.039)	(0.075)
P_t^{coal}	-0.031	-0.780*	-0.031	-0.033	-0.197***	0.088
	(0.048)	(0.406)	(0.049)	(0.045)	(0.051)	(0.064)
P_t^{carbon}	0.190***	-0.325	0.224***	0.182***	0.245***	0.048
	(0.046)	(0.250)	(0.055)	(0.042)	(0.053)	(0.063)
T^{level}	-0.006***	-0.025**	-0.006***	-0.016***	-0.025***	-0.005
	(0.001)	(0.0098)	(0.001)	(0.003)	(0.003)	(0.007)
$(T^{level})^2$	0.0002***	0.0024*	0.0002***	0.0004***	0.0007***	0.000
	(0.000)	(0.0011)	(0.000)	(0.000)	(0.000)	(0.000)
$cons$	0.767***	3.429***	0.671***	0.597***	0.889***	0.603***
	(0.120)	(0.920)	(0.080)	(0.073)	(0.151)	(0.144)
$season_2$	-0.135***	-0.036	-0.144***	0.168***	-0.134***	-0.201***
	(0.019)	(0.040)	(0.019)	(0.016)	(0.017)	(0.028)
$season_3$	-0.138***	-0.040	-0.147***	0.167***	-0.131***	-0.200***
	(0.020)	(0.043)	(0.020)	(0.017)	(0.018)	(0.029)
$season_4$	-0.184***	-0.154	-0.184***	0.195***	-0.166***	-0.219***
	(0.025)	(0.124)	(0.020)	(0.016)	(0.020)	(0.027)
$season_5$	-0.314***	-0.182***	-0.323***	0.314***	-0.277***	-0.353***
	(0.020)	(0.046)	(0.020)	(0.015)	(0.017)	(0.026)
R^2	0.8128	0.4854	0.8475	0.8808	0.8316	0.8554
$Joint\ R^2$		0.8225			0.8859	
Homoskedasticity (p-value)	0.014	0.069		0.000	0.000	

Note: Standard errors are in () ; values in [.] represent the 95% confidence interval of the estimated threshold ; *, ** and *** refer respectively to the 10%, 5% and 1% significance levels. The Joint R-squared is calculated from the residuals of model (4).

Table 2 present the estimation results of the threshold model of electricity prices in Germany and France. This table also contains the estimation results from the corresponding linear models in columns (2) and (5), and underlines the irrelevance of inference when nonlinearity is not taken into account. Row (3) shows the estimated threshold $\widehat{p}$ and its 95% confidence interval. The estimated carbon price thresholds are 12.57 and 14.94 € /ton in Germany and France, respectively. These thresholds are significantly different from each other. Neither of theme appear in the 95% confidence interval of the other price threshold.

A detailed analysis of the results in the rightmost columns of Table 2 indicates that the behavior of the French electricity producers has varied depending on whether the level of the carbon allowance price is above or under the price threshold of 14.94 €/ton. When the carbon price is below the threshold, it is instantaneously reflected in the French wholesale electricity prices: a rise of 1% in the emission-permit price results in 0.245% higher French day-ahead electricity contract price. Conversely, when the emission-permit price exceeds the threshold, it is no longer reflected in the French day-ahead electricity contract price. A thorough analysis of the carbon spot price series and a comparison of the results with those in Ahamada and Kirat (2015) concerning the relationship between the carbon spot price and the French day-ahead electricity contract price during the second phase of the EU ETS are very informative and help to clarify the results. The in-depth scrutiny of the results reveals that the estimated carbon price threshold in France divides the data in two subsets corresponding perfectly to those obtained by the sample splitting based on the carbon spot price structural break of October 2008 highlighted in Ahamada and Kirat (2015): all the observed carbon prices before October 2008 are higher than the estimated threshold; and only less than 4% of the observed carbon prices after October 2008 are higher than 15.73 € /ton, the upper bound of the confidence interval of the estimated threshold. Figure 5 illustrates the coincidence between the results of the changepoint model and the threshold model for the French day-ahead electricity contract price. As changepoint models can be viewed as threshold models where time is the threshold variable, and the sequence of carbon prices coincides here with time, we can reasonably confirm the robustness of the results in Ahamada and Kirat (2015) regarding the impact of the carbon spot price on wholesale electricity prices in France. Indeed, the period during which the carbon allowance price is above the price threshold of 14.94 €/ton perfectly corresponds to the period before October 2008. During that period, the carbon spot price was not reflected in wholesale French electricity prices. This somewhat surprising result was already clarified in Ahamada and Kirat (2015) where various arguments have been mentioned depending on whether the carbon market is competitive or not. Under perfect competition, a possible explanation is that electricity producers faced uncertainties regarding the future of the EU ETS and thus adopted a wait and see attitude until the end of 2008 and the adoption of the European Union climate and energy package by the European Parliament.

Under imperfect competition, market manipulation by power producers may explain why the carbon price is not reflected in electricity prices when it is above the threshold. These issues discussed in Hahn (1984) and Misiolek and Elder (1989) can indeed aggravate carbon allowance market inefficiencies. Besides, Sijm et al. (2012) argue that firms pursuing other strategies besides profit maximization such as maximizing market share or sales revenues or operating by simple rules of thumb may affect the carbon cost pass-through. Some of these market strategies may thus lead to market manipulation. The free allocation of carbon emission allowances which prevailed during the second phase of the EU ETS makes this later argument more plausible as it fosters strategic behaviors.

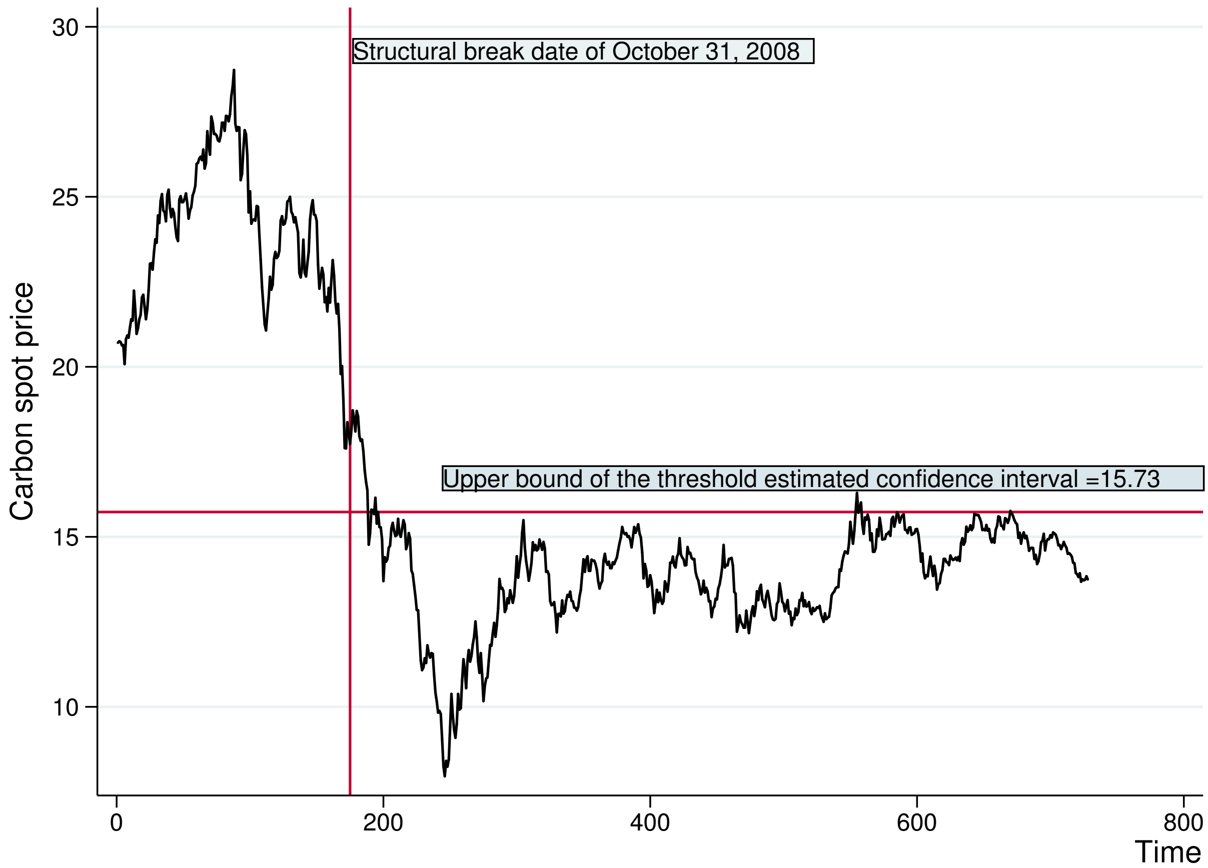

Figure 5: Splitting the carbon spot price series: changepoint versus threshold model (French case)

The period during which the carbon allowance price is below the price threshold of 14.94 €/ton corresponds to the period after October 2008. During that period and as mentioned above, the impact of carbon spot price on the French wholesale electricity prices is highly significant. In this regime, there is a strong evidence of trade-offs between gas and coal in producing electricity. Indeed, both gas and coal prices determine the price of electricity: 1% higher gas prices result in 0.205% higher electricity prices and 1% higher coal prices result in 0.197% lower electricity prices. However, this result is slightly different from those in Ahamada and Kirat (2015) since coal prices were found to have no impact on French electricity prices. This is may be due to the slight difference between samples. Moreover, testing for a threshold model of electricity prices in France when restricting the sample to the period after October 2008 do not reject the null hypothesis of linearity. Hence, the robustness of our results.

We now turn to the analysis of estimation results of the German day-ahead electricity contract price. These indicate variations in the behavior of German electricity producers depending on whether the price of emission-permit exceeds or not the threshold of 12.57 €/ton. Below the threshold, the price of emission-permit is not reflected in the German day-ahead electricity contract price. When the price of emission-permit exceeds the threshold, it is instantaneously reflected in the German day-ahead electricity price: an increase of 1% in the carbon price is immediatly associated with an increase of 0.224% in the German day-ahead electricity contract price. The carbon price threshold here do not split observations according to the structural break detected in Ahamada and Kirat (2015) as was the case for France. Moreover, testing and estimating a threshold model of electricity prices in Germany when restricting the sample to the period after October 2008 gives the same carbon price threshold. Consequently, the estimated model appears to be reasonable in that the estimated carbon price threshold is robust to the structural change occured on October 2008. In the high carbon price regime, carbon price as well as gas price are reflected in German electricity prices. The coal price do not impact on German electricity prices. In the low carbon price regime, the carbon price is no longer a determinant of German electricity prices. Figure 6 gives a visual feeling of the sample splitting between high and low carbon price regimes. It shows that the low regime mainly corresponds the period from January 15, 2009 to April 8, 2009. A possible explanation is that free allocation of carbon emission allowances causes that threshold effect. If low carbon prices reflect the disappearing of the scarcity effect, electricity producers do not need to buy carbon allowances as they get them for free. Hence, they do not pass-through their price into electricity prices.

Although carbon prices are found to be non reflected in German electricity prices before October 2008 in Ahamada and Kirat (2015), Figure 6 shows that the high carbon price regime includes carbon prices before October 2008. This raises some questions about the parameter stability in the high carbon price regime. To see whether this is the case, we test the stability of the whole estimated coefficients in the high carbon price regime over the periods before and after October 2008 using a Chow test. The test suggests that the relationship between the price of electricity in Germany, fossil-fuel prices and the carbon spot price in the high carbon price regime is unstable over the whole period. This relationship changed after October 2008. We thus compare estimated models of German electricity prices in the high carbon price regime over two sub-periods: before and after the carbon price structural break of October 31, 2008.[6] Table 3 shows the estimation results of the models of German electricity price in the high carbon price regime by sub-periods.

[6]This break-date is detected using the additive outlier (AO) procedure of the unit-root test with a change in the mean by Perron and Vogelsang.

Figure 6: Splitting the carbon spot price series: changepoint and threshold models (German case)

Table 3: Estimation results of German electricity prices in the high carbon price regime

Regime	High carbon price regime: P_t^{carbon} >12.57€			
Time period	Before October 2008		After October 2008	
P_{t-1}^{elec}	0.414***	(0.133)	0.597***	(0.055)
P_t^{gas}	0.691***	(0.170)	0.151***	(0.057)
P_t^{coal}	-0.048	(0.086)	-0.004	(0.069)
P_t^{carbon}	0.172	(0.124)	0.279**	(0.116)
T^{level}	-0.020*	(0.010)	-0.007***	(0.002)
$(T^{level})^2$	0.0007*	(0.000)	0.0002***	(0.000)
$cons$	-0.226	(0.593)	0.648***	(0.248)
$season_2$	-0.068*	(0.040)	-0.155***	(0.022)
$season_3$	-0.098**	(0.046)	-0.147***	(0.022)
$season_4$	-0.148***	(0.042)	-0.179***	(0.022)
$season_5$	-0.282***	(0.044)	-0.327***	(0.022)
R^2	0.657		0.745	

Note: Standard errors are in () ; values in [.] represent the 95% confidence interval of the estimated threshold ; *, ** and *** refer respectively to the 10%, 5% and 1% significance levels. The Joint R-squared is calculated from the residuals of model (4).

Over the period before October 2008, the estimated coefficient on carbon spot price is insignificant at conventional significance levels. So, the price of carbon does not matter for electricity price over that period. This is consistent with the estimation results in Ahamada and Kirat (2015) and can be interpreted in a similar way as for the French case above. Over the period after October 2008, the estimated coefficients of electricity price model in the high carbon price regime are very close to those in the fourth column of Table 2, except the coefficient of carbon price. In the high carbon price regime, an increase of 1% in the carbon price is immediatly associated with an increase of 0.279% in the German day-ahead electricity contract price. In summary, the price of carbon was not reflected in electricity prices before October 2008 in both countries. After October 2008, the carbon spot price impacts on the French wholesale electricity price in a linear way: a rise of 1% in the emission-permit price results in 0.245% higher French day-ahead electricity contract price. Over that period, the carbon spot price impacts on the German wholesale electricity price non-linearly. When the carbon spot price is lower than the threshold of 12.57 €/ton, it is not reflected in the German day-ahead electricity contract price. This low carbon price regime mainly corresponds to the period from January 15, 2009 to April 8, 2009. Conversely, when the carbon price exceeds the threshold, it is instantaneously and highly reflected in the German day-ahead electricity contract price: an increase of 1% in the emission-permit price results in 0.279% higher German day-ahead electricity contract price.

4 Conclusion

In this paper we have estimated the relationship between electricity prices and the prices of both the primary energies used in electricity generation and carbon dioxide emission permits in both France and Germany, using a nonlinear threshold model. To take full advantage of this modeling, we have compared the results with those in Ahamada and Kirat (2015). The results are very informative and reveal heterogeneity in the response of the electricity-generation sector to carbon constraints. Both French and German electricity producers do not include the emission permit price in the cost of electricity generation before 2008. After October 2008, French electricity producers pass through the emission permit price to electricity price in a linear way, while their German counterparts do it non-linearly. When the carbon spot price is higher than the threshold of 12.57 €/ton, German electricity prices are more sensitive to carbon constraints than French electricity prices. This behavior reflects the composition of the French energy mix relative to the German energy mix. The predominance of non-fossil energy sources in France means that there is less need to use emission permits.

This paper is a deepening of the results in Ahamada and Kirat (2015) relative to the impact of the second phase of the EU ETS on electricity wholesale prices. It mainly shows their robustness and overcomes some shortcomings.

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